vary with food availability in the environment and may also vary with species of fish. Shocking at intervals of less than 3 months may be too frequent for some species in the field. Protocols for growth studies in the field should be designed with these considerations in mind.

Acknowledgment.—We thank W. C. Kyker for his assistance in the laboratory. This is publication 3022 of the Environmental Sciences Division, Oak Ridge National Laboratory.

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North American Journal of Fisheries Management 7:450–453, 1987

Submerged, Electrically Shielded Live Tank for Electrofishing Boats[1]

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Abstract.—Fish caught by electrofishing are usually held in live tanks before appropriate data are recorded; however, if the tank water is not circulated, changes in water temperature and oxygen concentration may harm the fish. Also, if the water is circulated by pumps or other mechanical means, the power required may reduce the effectiveness of the electrofishing gear. We designed and successfully used a live tank which is submerged through the hull of a catamaran-type white-water raft. The live tank is placed in the water being electrofished so that power-free but continuous water circulation is maintained. Fish in the tank are protected from the electrofishing field by the design of the tank, which uses to advantage a phenomenon known as Faraday shielding. The tank is easy and inexpensive to construct and safe to use.

In electrofishing operations where the capture and live-release of fish is required, the size of the holding facility or live tank and its water quality affect the efficiency of the operation. An optimal live tank contains adequate supplies of fresh water at temperature and dissolved oxygen levels similar to the conditions under which the fish were captured. Shocked fish can suffer unnecessary trauma if they are exposed to a sustained electrical field (Hauck 1949; Pratt 1954), so it is important that there is no electric current in the live tank or, if there is, that it be of such low density that it is below the threshold of significant effect on the fish. Also, because each electrofishing effort requires varying lengths of time to "power-up" and "power-down," one needs to capture as many fish as possible during each power-up period. If a live tank is crowded with fish, or if they remain in a

[1] This paper is contribution 1 of the Glen Canyon Environmental Studies Project, sponsored by the U.S. Bureau of Reclamation, Upper Colorado River Division, Salt Lake City, Utah.

tank without circulating fresh water for more than a few minutes, the temperature and oxygen levels are altered and damage to the fish may occur. Live tanks capable of providing an appropriate degree of environmental equilibrium are usually supported by mechanical systems for circulating air and water. Pumps for these systems require continuous power, which often draws from and diminishes the power source used for the fishing effort.

In this paper, we present a design for a live tank that uses no mechanical devices, yet allows fresh water to be circulated continually. The design is based on a novel application of the physical laws of an electrical field known as Faraday shielding (Fortgang and Hwang 1984). The tank design allows rapid recovery of the fish after capture as well as providing them with an optimum environment during the holding process.

We have been involved with electrofishing efforts in the Grand Canyon since 1977 (Carothers 1985). Study objectives included determining the distribution, abundance, and growth of a variety of species, including the endangered humpback chub *Gila cypha*. Not only is returning healthy fish to the river critical to the eventual success of the project, but also we are required by the U.S. Endangered Species Act to be especially conservative in the handling of endangered species. Within the Grand Canyon section of the Colorado River, however, a fast current and frequent rapids make it difficult for the electrofishing crews to dictate when, where, or how frequently they can stop to analyze and then release the catch. It is not uncommon for fish to remain in the holding tank for one or more hours before we have a chance to secure the raft in a quiet eddy, where processing of the captured fish can proceed. Occasionally, inclement weather or the lateness of the hour (almost all our electrofishing is performed at night) can result in some fish remaining in the live tank overnight.

The Colorado River and its tributaries in the Grand Canyon that have been included in our electrofishing surveys have conductivity ranges of 250 to 1,200 μS/cm and water temperatures ranging from 5 to 20°C. The temperature of the main river does not exceed 12°C owing to the hypolimnetic water releases originating at Glen Canyon Dam (Carothers and Johnson 1983).

Our tank is a galvanized steel livestock watering trough, 60 cm deep × 60 cm wide × 95 cm long (Figure 1). Holes, 1.5 cm in diameter, were drilled in the sides and bottom of the tank but, to avoid turbulence in the tank when the raft was moving forward, none were drilled in the front panel. The inside was lined with galvanized steel hardward cloth (6-mm aperture diameter), which was soldered to it; this reduces the effective electrical diameter of the openings to provide better electrical shielding and also prevents the escape of small fish.

The tank is attached to the boat so that it extends about 30 cm into the water. Any metallic object in contact with an electric field will carry an electric charge (voltage), and the normal safety precautions recommended for electrofishing boats should be followed to prevent accidental shock. These precautions include mounting the electrodes away from the boat on nonconductive booms (e.g., fiberglass poles), wearing rubber gloves and boots, and connecting the metal surface of the tank, by wire or cable, to the frame of the raft or boat from which it is suspended. It is important also to be constantly aware that the operation of high-voltage electrical systems must be given proper respect.

Although the tank is positioned directly in the electrically charged water, the metal surface of the tank "short circuits" the electric field. Thus, when the tank is partly filled with an electrolyte (water with dissolved salts), *there will be virtually no electric current flowing inside the tank.* Fish placed in the tank water demonstrate virtually no effect of the electricity, even when they come in direct contact with the metal surface. As the ions comprising the flow of electric current approach the holes, they are attracted to the metal edges and most do not enter the tank. This shunting effect is enhanced by the phenomenon known as Faraday shielding (an electrostatic shield created with conductor, ground, and a series of parallel wires). The electron current flowing in the metal around the holes produces an electromagnetic field across and extending outward from the holes. The moving positive ion carries its own electromagnetic field. The interaction of three fields (one between the electrodes, one across the apertures in the tank, and one associated with the ion) combine vectorially to cause the ion to follow a curved path away from the apertures in the tank. Fish can survive for long periods in this protected environment while the electrofishing operation is taking place.

A live tank of this design has been used successfully during the live capture and release of over 25,000 fish (15 different species) in the Grand Canyon. There are no theoretical or empirical reasons why similar results would not be obtained in waters of any conductivity at all voltage levels normal to

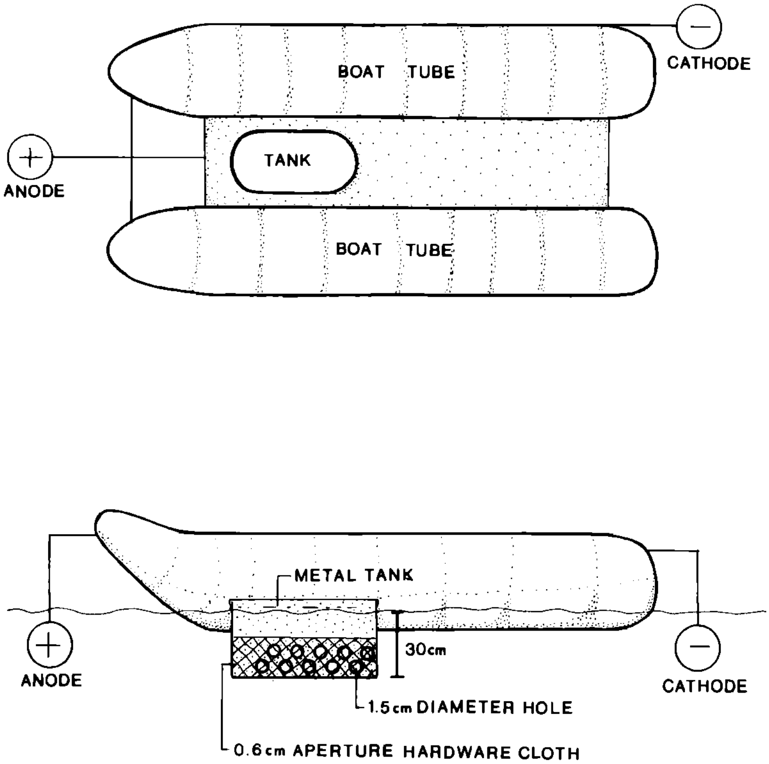

FIGURE 1.—Overhead and side views of a catamaran electrofishing raft showing the Faraday-shielded live-tank design and arrangement.

lake and river electrofishing. Although direct current is preferred for electrofishing, the tank is equally effective with alternating current. If very high voltages are used (above 350 peak volts) or if the conductivity of the water is higher than 1,200 μS/cm, the hardware cloth should have a mesh diameter of no more than 3 mm. The smaller aperture increases the strength of the Faraday shield across the opening and also offers greater electrostatic attraction of ions to the metallic edges of the holes. In practice, observing the fish in the tank will demonstrate whether or not there is adequate shielding if direct current is used. If a small electrical field does develop inside the tank, the fish will respond by aligning themselves with their heads pointing to the most positive electrical point (the anode) and by pressing their bodies against the conducting walls of the tank. If these behavioral patterns are noticed, the voltage output to the electrodes should be reduced until the fish activity returns to normal. This will assure the maximum rate of recovery from the trauma associated with electrofishing. Our tank was mounted through the boat hull, but it is also possible to position one or more tanks alongside the electrofishing craft.

Two additional variations of this type of live tank are possible. The galvanized steel tank could be drilled with smaller holes and no internal lining of hardware cloth used. If this is done, care must be taken to smooth the rough edges of the holes to avoid injury to the captured fish. A strong plastic tub also could be used in place of the galvanized steel container but, because the plastic is not electrically conductive, the galvanized hardware cloth would have to be installed to provide the electrical shunt effect.

Acknowledgments.—Otto Franz of the Lowell Observatory gave freely of his time in technical as well as editorial advice. George Goslow, Northern Arizona University, provided information on the neuromuscular responses of fish to electrical stimulation. Jim deVos, Bill Persons, and Henry Maddux of the Arizona Game and Fish Department gave freely of their resources during the developmental phases of the project. Michael Yard and Brian Dierker provided all the logistical support necessary for electrofishing in the Grand Canyon, and Marion Sharp prepared the illustration and participated in several field expeditions. Roberta Wallace provided substantial editorial assistance.

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North American Journal of Fisheries Management 7:453–455, 1987

Use of Tetracycline to Mark Otoliths of American Shad Fry

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Abstract.—Fry of American shad *Alosa sapidissima* were treated with tetracycline antibiotic (50 mg oxytetracycline-hydrochloride/L) by immersion in 1,200-L circular tanks. Treatment duration was 12 h/d for four consecutive days from 15 to 18 d of age. Ninety-eight percent of 57-d-old fish and 82% of 152-d-old fish showed acceptable marks on their otoliths (sagittae). Overall, marked fish treated and held outdoors and exposed to direct sunlight retained discernible marks at a slightly lower rate (85%) than those treated and kept indoors (94%). This technique permits mass marking of intensively cultured American shad fry and provides a means to determine the relative contribution these fish make to emigrating juvenile stocks.

The restoration of American shad *Alosa sapidissima* in the Susquehanna River basin has been undertaken in two ways. One method is to trap prespawning adults from other rivers and transfer them to the Susquehanna. The second is to intensively culture and stock large numbers of fry less than 20 d old. The relative contributions of these methods to the number of American shad emigrating in late summer and fall has not been established. A mass mark on either group of fish would make it possible to estimate the respective contributions. We concluded that immersion treatment could be used to incorporate a tetracycline mark into the calcium of proliferating bone tissue of intensively cultured American shad fry. Limited success has been obtained when fish were immersed in a tetracycline solution (Weber and Ridgeway 1962; Choate 1964; Scidmore and Olson 1969).

A mass mark for American shad fry must meet certain criteria. First, it must be administered to small fish (less than 15 mm total length), because the majority of American shad fry are stocked in the Susquehanna before they are 20 d old. Second, American shad suffer substantial mortality under even the slightest handling stress, so handling during marking must be minimal. Finally, young American shad fry are currently reared primarily on live *Artemia*; thus, the marking material could not be incorporated into the diet.

Otoliths are the only structures that appear to be calcifying when American shad are less than 20 d old, as determined from a preliminary study.

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